# PATENT SPECIFICATION

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COMPLETE SPECIFICATION.

## Apparatus for Applying Electrical Currents to the Body.

I, MORTON SMART, D.S.O., M.D., of 40, Park Lane, London, W. 1, a British subject, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to electro medical apparatus and has for its object to provide apparatus capable of producing painless graduated muscular contraction under complete control of the operator.

It is well known that the secondary current produced by an ordinary induction coil with the usual type of make and break, even when controlled by a laminated iron core, produces spasmodic movement of the muscles when applied to the human body, and is therefore incapable of use for fractures and unadvisible for most other muscular remedial measures.

I have discovered however that it is possible to produce painless graduated muscular contraction under complete control of the operator by means of alternating current of a special form described hereinafter, and my invention consists in the hereinafter described apparatus for producing this alternating current comprising an induction coil having a variable inductive coupling between the primary and secondary circuits and provided with a make and break device which breaks the primary circuit gradually so that the average rate of collapse of the field due to each interruption of the primary is substantially equal to the average rate of growth thereof.

Whilst not attempting to explain the reasons underlying the physiological result obtained, it has been found that the particular form of current produced coupled with a large range of control in the secondary circuit imparts a muscular stimulation of such a nature as cannot otherwise be obtained, and for the purpose of identification oscillograph curves illustrating the changes in potential in the secondary winding of the inductance form part of the drawings hereinafter described.

Reference will now be made to the accompanying drawings which illustrate an apparatus constructed according to the invention and in which:—

Figure 1 is a diagram showing the disposition of the elements constituting the apparatus and the electrical connections.

Figure 2 is a longitudinal sectional elevation of the mercury interrupter.

Figure 3 is an oscillograph diagram illustrating the changes in potential in the secondary winding of the inductance, and

Figure 4 is a similar diagram taken at slower speed and comparing the current flow in the primary winding and the change of potential in the secondary winding.

In the drawings Figure 1 indicates a base plate upon which are mounted an electric motor indicated diagrammatically at 2, and a rotary circuit interrupter similar indicated at 3 which is rotated by the motor. The motor 2 is supplied with current from supply mains connected to terminals 4 and in order to control the speed of the motor a series of resistance plates 5 is interposed in the motor circuit which also includes a rheostat (not shown) connected to terminals 6 and a five position switch 7 by adjustment of which the number of resistance plates 5 in circuit is controlled. Alternatively, a rheostat of suitable resistance may be used and the resistance plates and five point switch dispensed with. The primary winding of an inductance coil is indicated at 8, and this coil

is supplied with current from a battery 9, the poles of which are connected to terminals 10 on the base plate 1, one of these terminals being connected to one of the terminals 11 of the interrupter and the other to one of a pair of terminals 12 connected directly to the winding. The second terminal 11 of the interrupter is connected to the second terminal 12 and the connection 13 between this terminal and the primary winding 8 includes a pair of switches 14 and 15, the former of which can be operated independently to open the interrupter circuit and the latter of which is inter-connected with a switch arm 16 adapted to open or close the motor circuit, by a common operating arm 17 so arranged that as long as the switch member 14 remains closed, the motor and primary winding circuits can be opened or closed simultaneously. In use the apparatus also includes a secondary winding connected to a contact member or members which being of usual construction and arrangement are not illustrated.

It is preferred to employ a mercury interrupter; a suitable construction of which is shown in Figure 2, and comprises a spindle 18 connected by an insulated spring coupling to the spindle of the motor 2 and mounted in ball bearings 19 disposed in a housing 20 mounted in a supporting framework 21 and electrically insulated therefrom by insulating sleeves 22. A second portion 23 of the framework is attached to the portion 21 by bolts 24, the two portions when assembled retaining a glass cylinder 25 between them, thereby enclosing a space 26 into which a quantity of mercury is introduced through a passage 27 normally closed by a screw cap 28. The inner end of the spindle 18 carries a revolving contact member 29 to which one of the terminals 11 is connected, the other being connected to the base of the mercury chamber 26.

To enable the level of mercury in the chamber 26 to be adjusted a member 30 is provided mounted on the inner end of a spindle 31 disposed in the frame portion 23 and having at its outer end a knurled or milled hand wheel 32 for manual adjustment of the position of the member 30. To damp out or prevent any wave or surge which may develop in the mercury by the impact of the revolving contact 29 a shield 33 is provided having a slot 34 through which the contact arms pass during rotation.

In the operation of the apparatus above described the contact member 29 is rotated so as to accomplish preferably 1800 revolutions giving 3600 electrical cycles per minute and the effect has been found to be that as the member 29 strikes the mercury making sudden and complete contact a magnetic field is built up with comparative rapidity in the inductance causing the potential across the secondary winding to rise. During that portion of the period of contact between the mercury in the glass container and the member 29, while the flow of primary current and the intensity of magnetic field is practically constant, the induced potential begins to decrease. Owing, however to the inductance or electrical inertia of the coil, the fall of the induced potential takes an appreciable time and before it reaches zero value the member 29 leaves the mercury and interrupts the primary current with the result that the magnetic field collapses, the induced potential falls to zero, and owing to the collapsing field changes its sign and again increases until the final and complete extinction of the magnetic field allows the induced potential to fall to and to remain at zero value until a new cycle begins.

The sequence of operations described in the preceding paragraph will be better understood by reference to the diagrams in Figures 3 and 4 which are copies of oscillograms obtained from a Duddell oscillograph with an apparatus constructed according to the invention. The oscillogram of Figure 4 was taken when the apparatus was running at about one quarter the normal speed and with less than normal resistance in circuit so as to produce on as large a scale as possible a diagram of one complete cycle of operations. Of the two curves shown in this diagram, the one appearing as a full line shows the potential variation across the terminals of the secondary winding and the one appearing as a broken line shows the current flowing in the primary winding during the period cover by the first named curve. The point A at which the two curves diverge is that at which the member 29 makes contact with the mercury and the primary current begins to flow, the quantity increasing up to the point B. From A to L the increase in the strength of the magnetic field is rapid and the induced secondary voltage rises from A to C (full line curve). From L to B (broken curve) the increase of current flow is negligible, the magnetic field remains practically constant and consequently the induced voltage falls from its maximum strength indicated by C to about the point D at which the member 29 leaves the mercury (point B on broken curve) but the cessa-

tion of current flow is not instantaneous owing largely to the fact that the member 29 carries with it a certain amount of mercury or mercury vapour which is drawn out and burns as a momentary mercury arc thereby introducing a gradually increasing resistance into the primary circuit and preventing the more rapid collapse of the magnetic field. This retarding effect on the collapse of the magnetic field prevents the excessive rise of induced potential, which would otherwise take place, in the secondary circuit. The lessening of the primary current is indicated by the portion BF of the broken curve and whilst this is occurring an increase of voltage but of opposite sign is induced in the secondary winding and the curve passes from D to E (full line curve). Beyond F the rate of change of current flow in the primary winding is practically *nil* so that the induced voltage falls rapidly from E to zero, thus completing the cycle. When the speed of the apparatus is increased to the normal rate, the diagram obtained on the oscillograph is as shown in Figure 3 from which it will be seen that in the curve showing the potential variation in the secondary winding the hump D of Figure 4 almost disappears and the course from C to E becomes practically a straight line.

The form of the alternating current produced is of great importance and the apparatus must be designed so that the form of the current is or closely approximates to that indicated by the diagrams given. The amplitude of the alternations of the current is a variable quantity dependent amongst other things on the initial voltage across the primary coil and the amount of magnetic coupling between the windings of the transformer, but the form of the current is determined by the time intervals between make and break in the primary circuit, the nature of the interrupter, the self-induction of the coil and other physical constants of the instrument. As an example of the type of coil with which satisfactory and painless muscular excitation is obtained, the following particulars are given:—The spool consists of a fibre tube one inch in outside diameter and .75 inch inside diameter and having flanges 4.6 inches apart. Within the fibre tube is disposed the movable core consisting of a bundle of soft iron wires, the outside diameter of the bundle being about .6 inch. The primary winding is of double cotton covered No. 18 S.W.G. soft copper disposed in layers with tappings so that two or more layers can be used as desired. The secondary winding consists of layers of silk covered No. 32 S.W.G. soft copper with tappings to allow of two, three or more layers being used. A coil constructed in this manner is used in conjunction with a 2-volt battery and a double arm contact maker running at 1800 revolutions per minute equivalent to 3600 cycles per minute which has been found to be the most satisfactory speed of operation. The regulation of the induced secondary current as applied to the muscles of the body, both in time and intensity, is effected and controlled by the insertion or withdrawal of the movable laminated core piece of the inductance coil. The operator is enabled to cause alternate painless contraction and relaxation of the injured muscle or group of muscles, and the type of contraction produced so closely stimulates the physiological contraction of a muscle, that the result is indistinguishable from a normal voluntary contraction.

The contraction produced is under the absolute control of the operator, and the rise and fall of the stimulus can be so accurately graduated that, starting from zero, it may be gradually increased to the maximum contraction which the muscle acted upon is capable of without damage, and the muscle then allowed to relax just as gradually, or if necessary it may be held in a state of contraction.

The contraction thus produced is in no way a local spasm of part of the muscle as is produced by the usual medical faradic coil, but is a wave contraction of the entire length of the muscle. A single muscle, or a whole group of muscles, may be contracted and relaxed in this way. A healthy group of muscles, when acted upon by such an apparatus, can thus be made to contract and relax rhythmically, so as to cause painless reproduction of the full movements of the joint upon which the particular group acts.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. The herein described electro-medical apparatus for producing alternating current of the form specified comprising an induction coil having a variable inductive coupling between the primary and secondary circuits and provided with a make and break device which breaks the circuit gradually so that the average rate of collapse of the field due to each interruption of the primary is substantially equal to the average rate of growth thereof.

2. Electro medical apparatus as claimed in Claim 1 wherein the make and break device consists of a mercury interrupter comprising a revolving contact member driven by an electric motor.

3. Electro medical apparatus constructed and adapted for use substantially as described with reference to the accompanying drawings.

Dated this 14th day of June, 1924.

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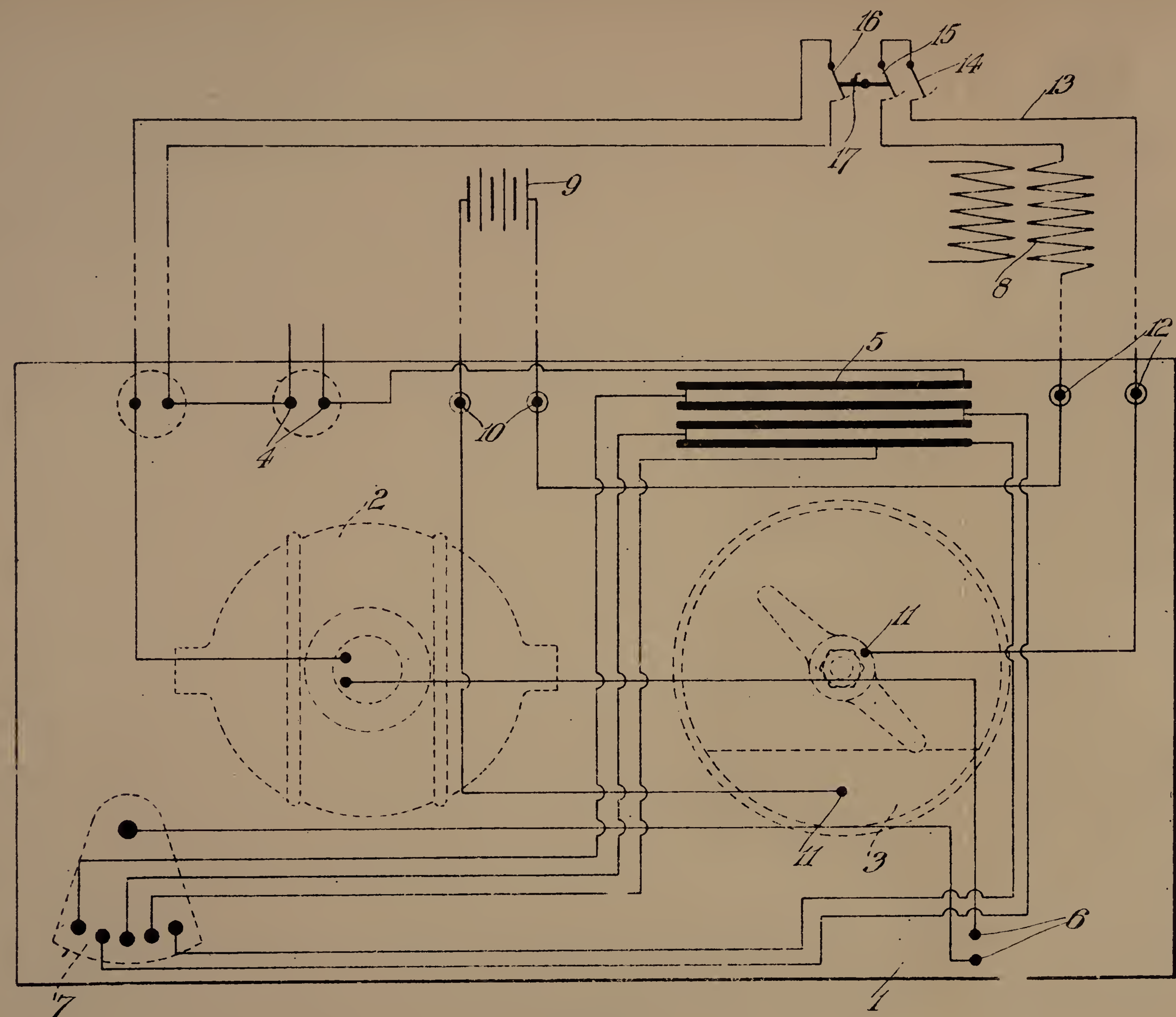


Fig.1.

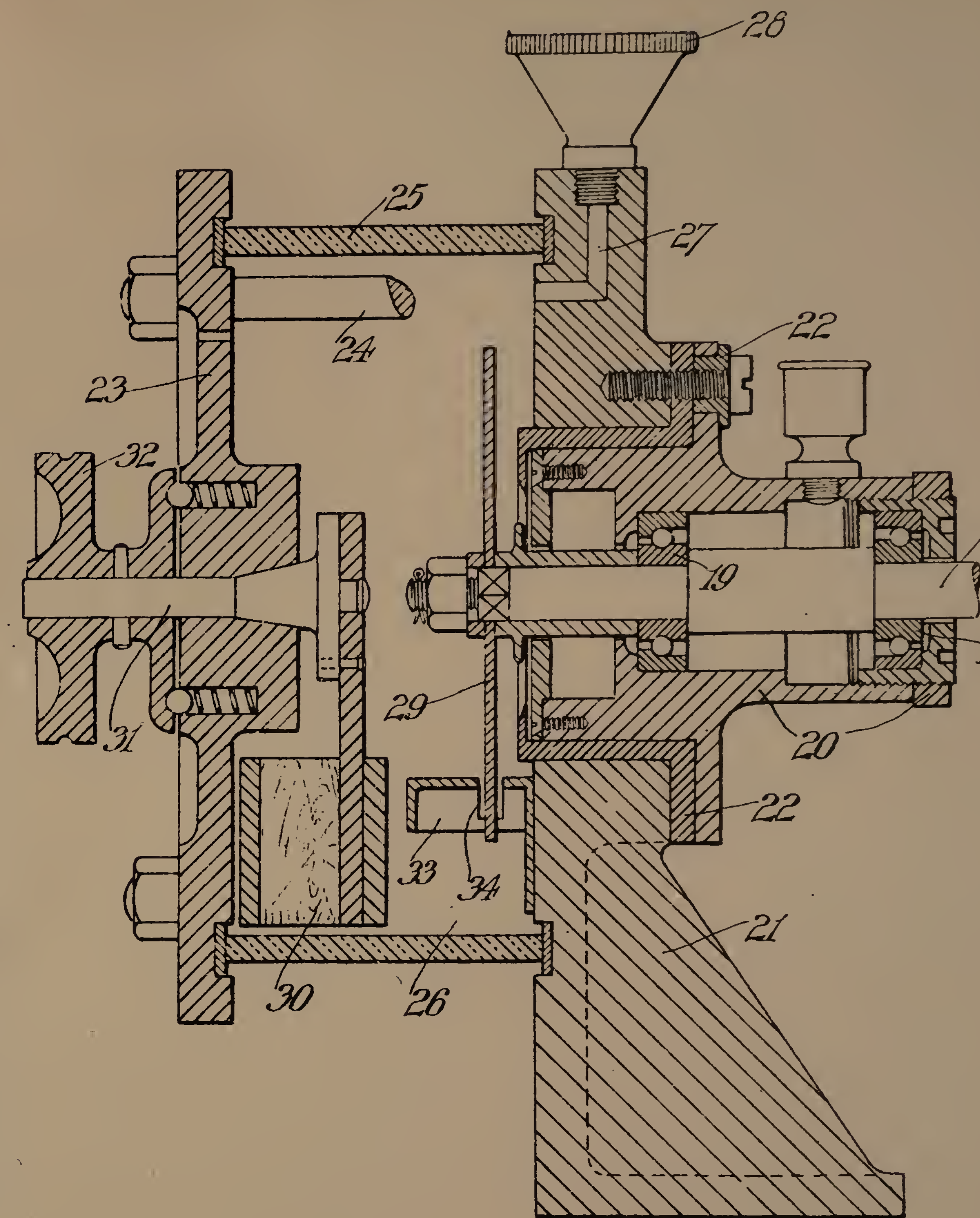


Fig.2.

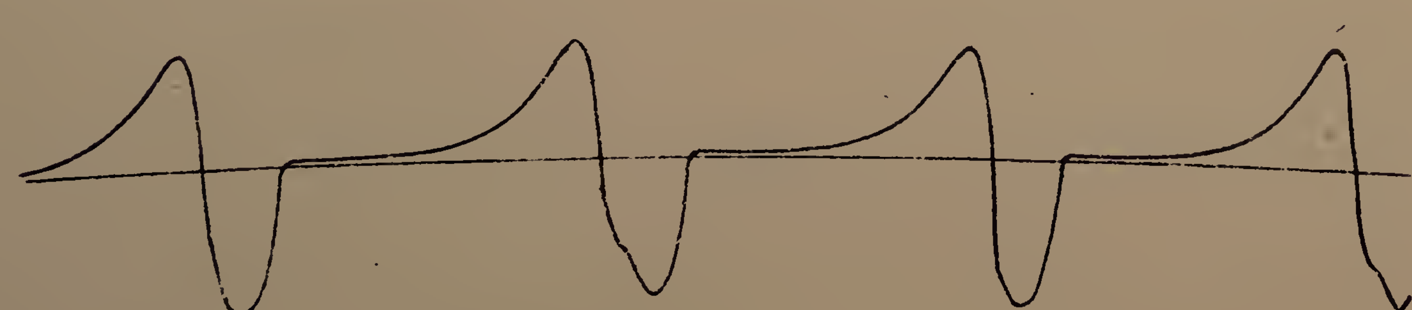

Fig.3.

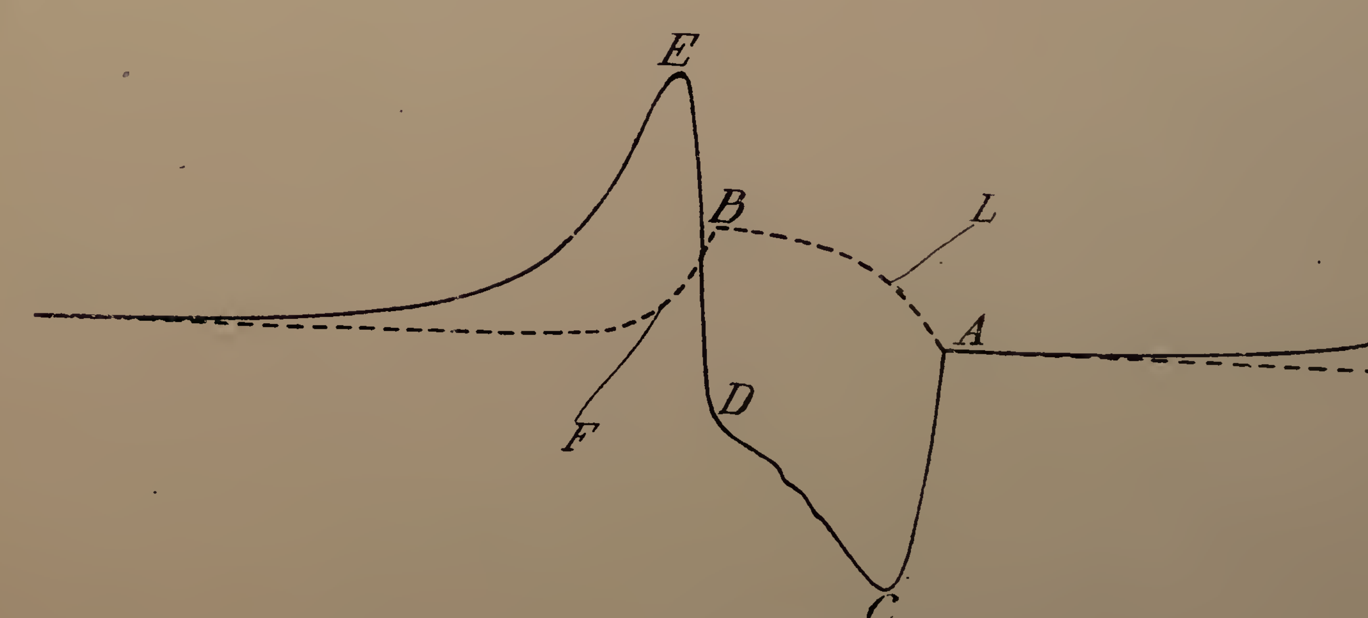


Fig.4.